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AIR FORCE FLIGHT DYNAMICS LABORATORY
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 WRIGHT PATTERSON AIR FORCE BASE OHIO



USER'S INSTRUCTIONS FOR COMPUTER PROGRAMS

JTSDL (Single & Double Lap Bonded Joints)
 JTSTP (Step Lap Bonded Joints)

Prepared by

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Technical Memorandum FBC-73-3

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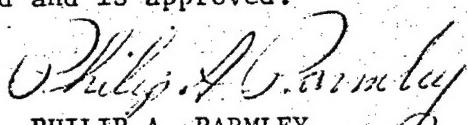
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**AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO**

FOREWORD

This work was conducted by Mr P. C. Carroll and Mr T. J. Muha,
Exploratory Development Group, Advanced Composites Branch, at the Air
Force Flight Dynamics Laboratory, under Project 4364, "Filamentary
Composites Structures," "Bonded Joint Analysis."

The manuscript was released by the authors in January 1973. This
Technical Memorandum has been reviewed and is approved.



PHILIP A. PARMLEY
Chief, Advanced Composites Branch
Structures Division

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PART I
GENERAL INFORMATION

1.1 Program Titles

This Technical Memorandum covers the input required to run two computer programs. The first program, JTSDL, analyzes single or double lap bonded joints. The second program, JTSTP, analyzes step lap bonded joints.

1.2 Background

These programs were written by Southwest Research Institute under contract F33615-69-C-1641 with AFFDL/FBC. The results of this contract are published in AFFDL-TR-72-97. Copies of the computer programs are available from AFFDL/FBC, Wright-Patterson AFB, Ohio 45433, Attn: Mr. T. Muha or Mr P. Carroll.

1.3 Program Descriptions

These programs deal with the nonlinear analysis of bonded joints subjected to static loads at room temperature. The joints are assumed sufficiently wide in the z-direction (perpendicular to the plane shown in Figures 1.1 - 1.3) so that a state of plane strain exists. The adherends may be either orthotropic (laminates) or isotropic, with each adherend having its own constant thickness. The adhesive is assumed to be isotropic with constant thickness. Normal stresses through the thickness and interlaminar shear are neglected. Also, each laminate is assumed to be symmetrical about its middle surface.

1.4 Definitions

The following nomenclature is used in this memorandum and in AFFDL-TR-72-97:

ν = Poisson's Ratio

G = Shear Modulus

E = Young's Modulus

m, n = Shape Parameters

σ_y = Secant Yield Stress

l = Longitudinal Direction

t = Transverse direction, in Plane of Lamina

x = Direction Along Joint Length

y = Direction Normal to Plane of Joint

1.5 Joint Geometries

The three joints, along with the coordinate systems, dimensions, and applied loads which are analyzed by these programs are shown in the following three figures.

Figure 1-1 Single Lap Joint

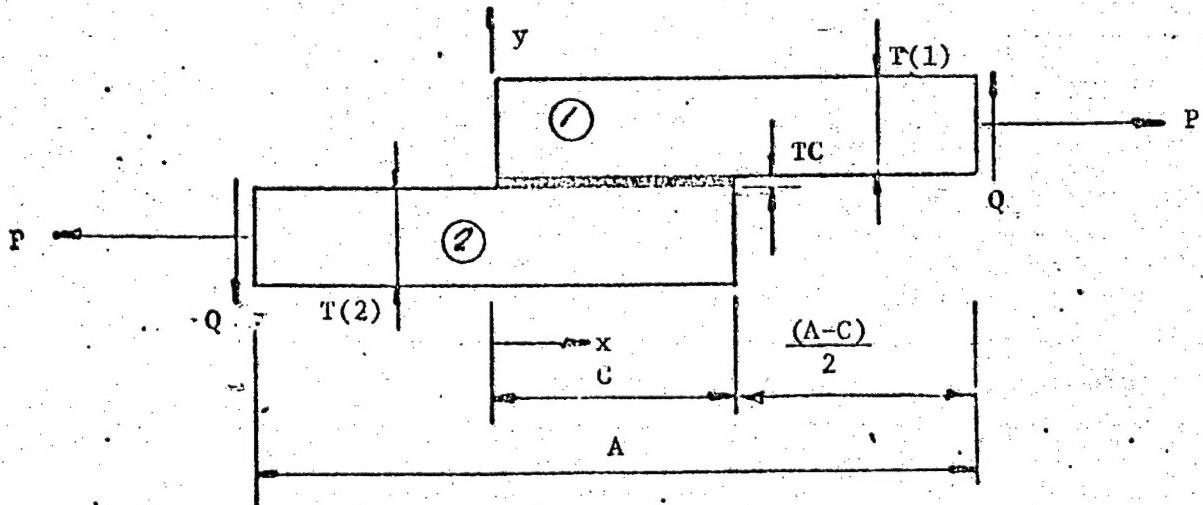


Figure 1-2 Double Lap Joint

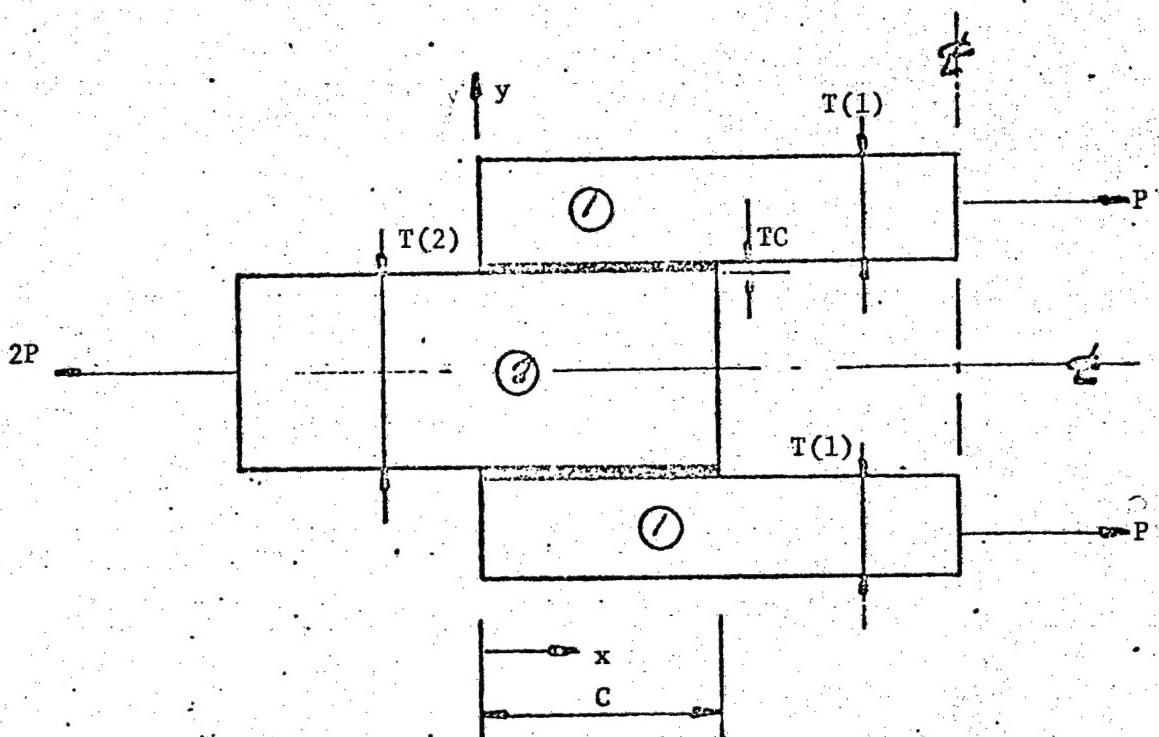
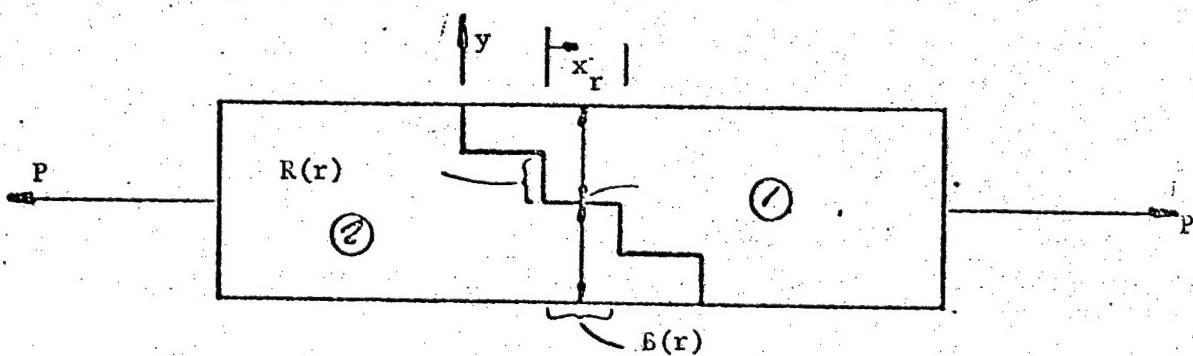


Figure 1-3 Step Lap Joint



Typical for step r
R steps in general (3 shown)

PART II
JTSNL INPUT

The input for the nonlinear analysis of single and double lap joints consists of ten logical cards. A logical card may consist of more than one actual, physical card. In the following explanation, a logical card will be referred to as a card.

CARD 1: TITLE CARD

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|--------------------|
|----------------|---------------|-----------------|--------------------|

| | | | |
|------|------|-------|------------------------------|
| 1-70 | 10A7 | Title | Any alphanumeric information |
|------|------|-------|------------------------------|

| | | | |
|-------|-----|-------|----------------|
| 71-80 | I10 | KTYPE | Type of Joint: |
|-------|-----|-------|----------------|

1, for single lap,

2, for double lap

CARD 2: GEOMETRY, LOAD, ITERATION LIMITS

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|--------------------|
|----------------|---------------|-----------------|--------------------|

| | | | |
|------|-------|---|-------------------------------------|
| 1-10 | F10.0 | A | Total length of joint (See Fig 1-1) |
|------|-------|---|-------------------------------------|

| | | | |
|-------|-------|---|---------------------------------|
| 11-20 | F10.0 | C | Joint bond length (See Fig 1-1) |
|-------|-------|---|---------------------------------|

| | | | |
|-------|-------|---|---|
| 21-30 | F10.0 | P | Joint load (If P=0, the program will compute joint ultimate load) |
|-------|-------|---|---|

| | | | |
|-------|-------|------|---|
| 31-40 | F10.0 | XERR | Iteration error - left up to user's discretion (For SwRI value, see Appendix) |
|-------|-------|------|---|

| | | | |
|-------|-----|-----|--|
| 41-50 | I10 | NIT | Maximum number of iterations - left up to user's discretion (For SwRI value, see Appendix) |
|-------|-----|-----|--|

| | | | |
|-------|-----|---|---|
| 51-60 | I10 | N | Number of stations for numerical integration - left up to user's discretion (For SwRI values, see Appendix) |
|-------|-----|---|---|

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|---|
| 61-70 | I10 | NP | Flag for printing adherend stresses: 0, Print 1, Do not print |
| 71-80 | F10.0 | EFFK | Effective Bending Factor (See Appendix) |

NOTE: The user should carefully note the values of the correction factor EFFK suggested in the Appendix when assessing the desirability of using this program to solve his particular problems. (See Pages 146-149 of AFFDL-TR-72-97)

CARD 3: ADHESIVE PROPERTIES (ISOTROPIC)

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|--------------------|
| 1-10 | F10.0 | TC | Thickness |
| 11-20 | F10.0 | VC | Poisson's Ratio |
| 21-30 | F10.0 | GC | Shear Modulus |
| 31-40 | F10.0 | ESC | See Appendix |
| 41-50 | F10.0 | ENC | See Appendix |

CARD 4: GEOMETRY OF ADHEREND 1

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|---|
| 1-10 | F10.0 | T | Total Thickness |
| 11-14 | I4 | NL | Number of layers (Maximum of 61, 1 IF isotropic adherend) |
| 15-79 | 13F5.0 | ORNT(1,J) | Fiber orientation in degrees for each layer (Omit if isotropic) |

If more than 13 layers, continuation cards of format 16F5.0 are used.

CARD 5: ADHEREND 1 - LAMINA PROPERTIES

A. (Used for Laminated Materials Only)

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|--|
| 1-20 | F20.0 | E(1,1) | E_1 (See Appendix) |
| 21-30 | F10.0 | ES(1,1) | σ_1 (See Appendix) - Omit for linear curve |
| 31-40 | F10.0 | EN(1,1) | n_ℓ (See Appendix) - Omit for linear curve |
| 41-60 | F20.0 | E(1,2) | $-E_1/N_{lt}$ (See Appendix) |
| 61-70 | F10.0 | ES(1,2) | σ_{lt} (See Appendix) - Omit for linear curve |
| 71-80 | F10.0 | EN(1,2) | n_{lt} (See Appendix) - Omit for linear curve |

B. (Used for Isotropic Homogeneous Materials Only)

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|---|
| 1-20 | F20.0 | E(1,1) | E |
| 21-30 | F10.0 | ES(1,1) | σ (See Appendix) - Omit for linear curve |
| 31-40 | F10.0 | EN(1,1) | n (See Appendix) - Omit for linear curve |
| 41-50 | F10.0 | VA(1) | v |

CARD 6: CONTINUATION OF CARD 5A

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|--|
| 1-20 | F20.0 | E(1,3) | E_t (See Appendix) |
| 21-30 | F10.0 | ES(1,3) | σ_t (See Appendix) - Omit for linear curve |
| 31-40 | F10.0 | EN(1,3) | n_t (See Appendix) - Omit for linear curve |
| 41-60 | F20.0 | E(1,4) | G_{lt} (See Appendix) |
| 61-70 | F10.0 | ES(1,4) | τ_{lt} (See Appendix) - Omit for linear curve |
| 71-80 | F10.0 | EN(1,4) | m_{lt} (See Appendix) - Omit for linear curve |

NOTE: For an isotropic adherend, there is no Card 6.

CARDS 7, 8, & 9: ADHEREND 2

Cards 7, 8, & 9 are repeats of Cards 4, 5, & 6 using Adherend 2 data.

CARD 10: ALLOWABLES FOR ULTIMATE STRENGTH PREDICTION (See Note Below)

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|---|
| 1-2 | I 2 | KFAILC | Failure criterion for the adhesive (See Appendix) |
| 3-12 | F10.0 | SC=SU | Allowable shear stress (strain) for the adhesive |
| 13-14 | I2 | KFAIL(1) | Failure criterion for Adherend 1 (See Appendix) |
| 15-24 | F10.0 | STRSLF(1) | Allowable long. stress (strain) in Adherend 1 |
| 25-34 | F10.0 | STRSTF(1) | Allowable trans. stress (strain) in Adherend 1 |
| 35-44 | F10.0 | STRSLTF(1) | Allowable shear stress (strain) for Adherend 1 |
| 45-46 | I2 | KFAIL(2) | Failure criterion for Adherend 2 (See Appendix) |
| 47-56 | F10.0 | STRSLF(2) | Allowables for Adherend 2 |
| 57-66 | F10.0 | STRSTF(2) | Allowables for Adherend 2 |
| 67-76 | F10.0 | STRSLTF(2) | Allowables for Adherend 2 |

NOTE: This card is input only if P=0 on Card 2; if P≠0, omit Card 10.

PART III

JTSTP INPUT

The input for the nonlinear analysis of step lap bonded joints is identical to the input for JTSDL, except as noted below.

CARD 1

Omit the variable KTYPE.

CARD 2

Replace this card with the following cards:

CARD 2A: Geometry, Load, and Iteration Limits

| COLUMNS | FORMAT | VARIABLE | EXPLANATION |
|---------|--------|----------|--|
| 1-10 | I10 | NS | Number of steps |
| 11-20 | F10.0 | P | Loads |
| 21-30 | F10.0 | XERR | Iteration error tolerance |
| 31-40 | I10 | NIT | Maximum number of iterations |
| 41-50 | I10 | N | Number of stations for numerical integration |
| 51-60 | I10 | NP | Adherend stresses print flag |
| | | | 0, Print |
| | | | 1, Do not print |
| 61-70 | F10.0 | EFFK | Effective bending factor (See Appendix) |

CARD 2B: STEP CONFIGURATION

| <u>COLUMNS</u> | <u>FORMAT</u> | <u>VARIABLE</u> | <u>EXPLANATION</u> |
|----------------|---------------|-----------------|------------------------|
| 1-10 | F10.0 | R(1) | Height of first riser |
| 11-20 | F10.0 | B(1) | Length of first tread |
| 21-30 | F10.0 | R(2) | Height of second riser |

This is repeated until complete step geometry has been specified. More than one physical card may be required.

B(NS) Length of last tread

R(NS+1) Height of last riser

APPENDIX

CARD 2

COLUMNS

- (31-40) Tolerance used in Southwest Research Test Programs was (.025)
- (41-50) Number of iterations used in Southwest Research Test Programs was (20)
- (51-60) Number of stations for Southwest Research Programs was either
(31) or (61). 61 being primarily for single lap and 31 being
primarily for double lap joints.
- (71-80) K_e for Southwest Research Test Runs was (0.01) - single lap
(0.02) - double lap
(0.1) - step lap

CARD 3

COLUMNS

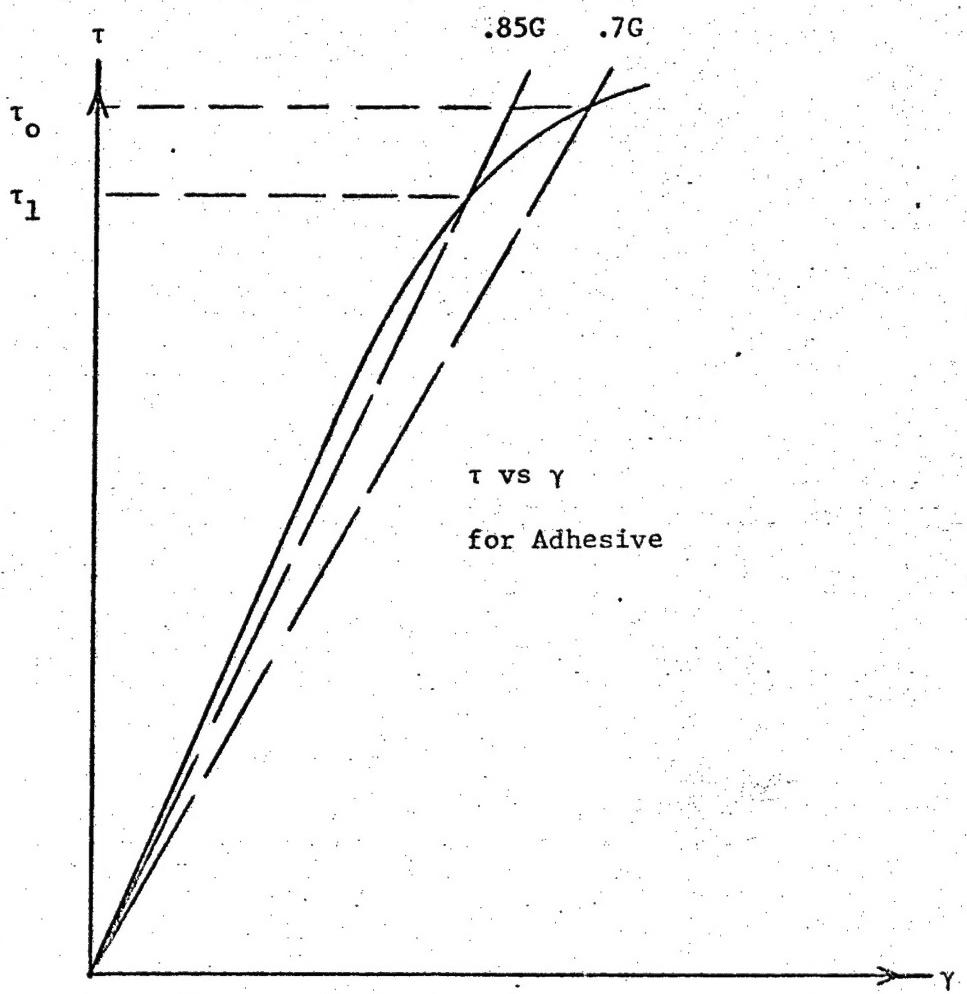
- (31-40) ESC obtained from shear stress vs strain curve for adhesive where
.7G line intersects the τ vs γ curve.
- (41-50) $n = \frac{1 + \log_{10}(17/7)}{\log_{10}(\tau_0/\tau_1)}$

where:

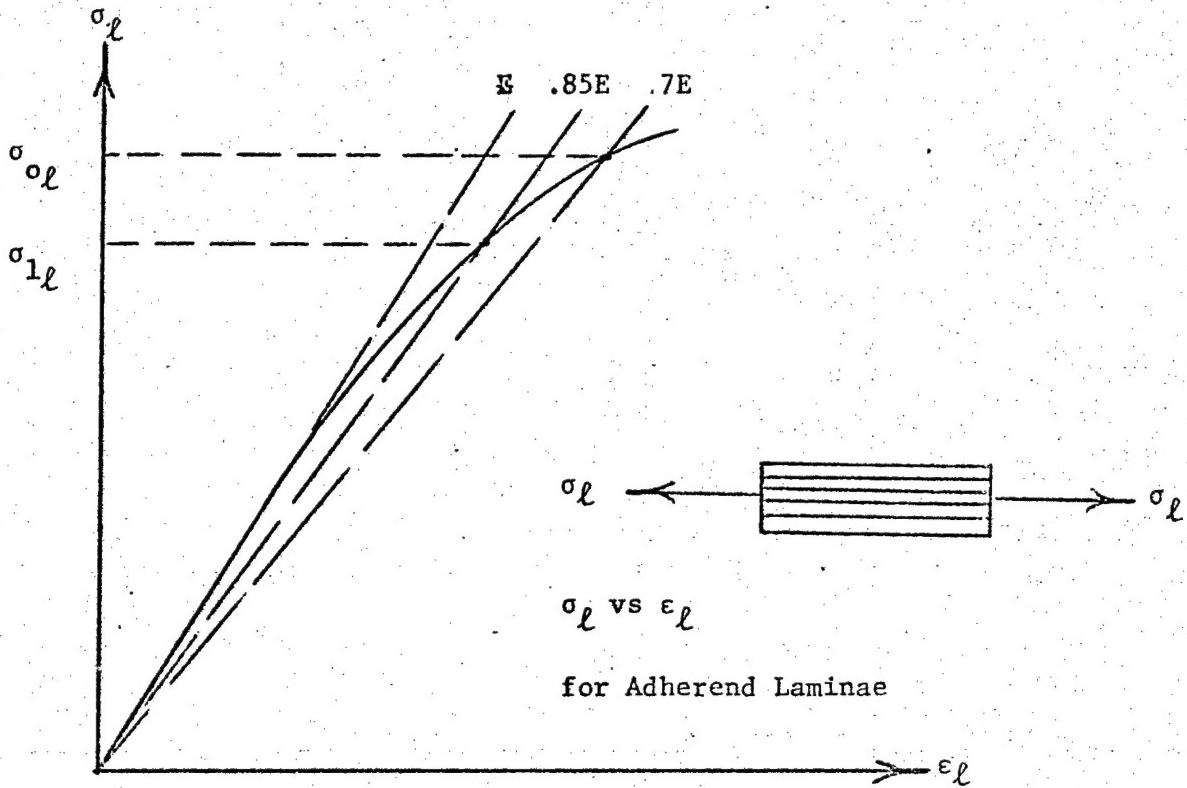
$$\tau_0 = \text{stress at secant modulus} = .7G = \text{ESC}$$

$$\tau_1 = \text{stress at secant modulus} = .85G = \text{ENC}$$

Taken from shear stress-strain curve for adhesive



CARDS 5 & 6



To obtain $E(1,1) - E_\ell$

$$E_\ell = \Delta \sigma_\ell / \Delta \epsilon_\ell$$

To obtain $ES(1,1) - \sigma_{0\ell}$

$\sigma_{0\ell} =$ Secant yield stress (stress at which the secant modulus = 0.7E)

NOTE: When the 0.7E secant modulus does not exist, the values to be used may be determined from the following formulae:

$$n = \frac{\log_{10} \left(\frac{E\epsilon' - \sigma'}{E\epsilon'' - \sigma''} \right)}{\log_{10} (\sigma'/\sigma'')}$$

$$\sigma_o = \frac{7}{3} (E\epsilon'' - \sigma'') (\sigma'')^{-n} \frac{1}{1-n}$$

Where σ' , ϵ' and σ'' , ϵ'' correspond to any two points on the stress strain curve.

To obtain $E_{lt} = n_\ell$

$$n_\ell = \text{shape factor} = 1 + \frac{\log_{10} (17/7)}{\log_{10} (\sigma_{o_\ell} / \sigma_{1_\ell})}$$

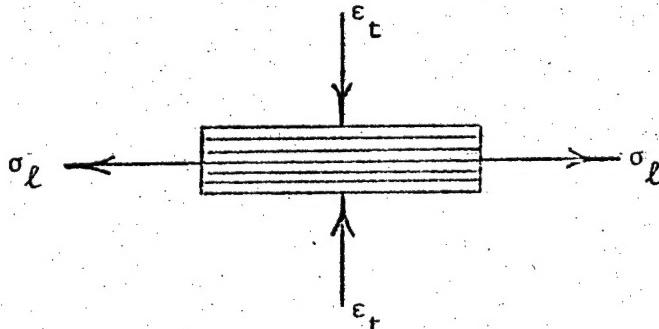
From graph:

σ_{o_ℓ} = stress at which the secant modulus = $0.7E$

σ_{1_ℓ} = stress at secant modulus at $0.85E$

To obtain E_{lt} , σ_{lt} , n_{lt}

σ_t vs ϵ_t plot for adherend necessary

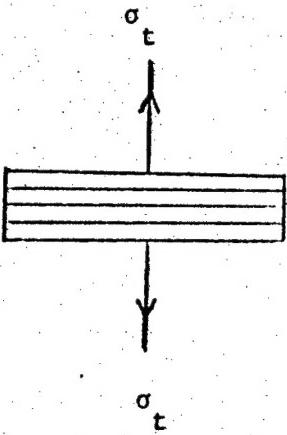


Then:

Analysis methods same as for E_ℓ , σ_{o_ℓ} , n_ℓ

To obtain E_t , σ_{o_t} & n_t

σ_t vs ϵ_t plot for adherend necessary

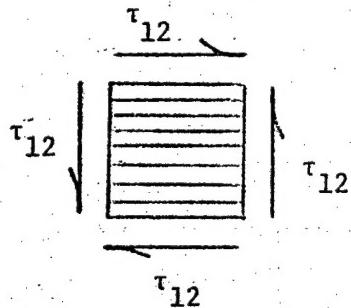


Then:

Analysis methods same as for E_ℓ , σ_{o_ℓ} , n_ℓ

To obtain G_{lt} , $\tau_{o_{lt}}$, n_{lt}

τ_{lt} vs γ_{lt} plot for adherend necessary



Then:

Analysis methods same as for E_ℓ , σ_{o_ℓ} , n_ℓ

CARD 10

- 1. Maximum stress = Allowable stress (for adhesive and isotropic adherends)**
- KFAIL = 2. Maximum strain = Allowable strain (for composite adherends)**
- 3. Von Mises stress = Allowable stress

** As used by SwRI, Ref. AFFDL-TR-72-97, see X. 2, p. 146